Flight Systems Research Quarterly

An informal newsletter by and for participants of the UCLA/NASA Flight Systems Research Center

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UCLA Students to Work at Dryden this Summer

As summer approaches, plans for more focused research, literature searches, industry co-ops, studying abroad, as well as those much-needed vacations (especially for graduate students finishing their June Ph.D. comps or prelims!), are beginning to take shape. At NASA Dryden, preparations are being made to accommodate several students associated with the UCLA Flight Systems Research Center that have expressed interest in conducting summer research full-time or part-time on-site at Dryden. In addition to furthering their degree progress, students will be able to gain valuable experience working firsthand at NASA's premier flight test center.

Among this group are Eric Shank (CS), Walter Chung (MANE), Dennis Braunreiter (EE), Chi-Chao Chang (EE), Gustave Stroes (MANE), Polwin Chan (MANE), as well as two undergraduates, John Griswold and Christina He, both of MANE. As a sampling of some of their tasks, Eric plans to continue his work on human factors engineering to optimize the computer work environment for complex systems, with help from NASA technical monitor Mary Shafer (XRDD), SR-71 Chief Engineer.

Dennis Braunreiter plans to perform a proof-of-principle test by setting up an outdoor laser beam propagation distortion experiment to detect scintillation/fluctuation patterns generated by wind flow (something the Mojave Desert has a lot of in the summer months). This is seen as a first step toward eventually conducting an in-flight study to estimate wind profiles from laser-scintillation-obtained refraction index patterns. Working closely with EE colleague Qian Lin, Dennis has shown this to be a promising technique in laboratory ground tests at UCLA.

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NASA Dryden Gives Pegasus a Lift into Orbit

The same NASA B-52 (#008) which was used to launch the famed North American X-15 rocket-powered research aircraft, launched the fifth Pegasus mission on May 19, 1994. Taking off shortly before 9:00 a.m. Thursday morning from Edwards AFB, the B-52 flew to a designated launch point 60 miles off the coast of Monterey before releasing Pegasus at 10:03 a.m. over the Pacific Ocean. The Pegasus space booster then roared into orbit using its three rocket stages before deploying its payload, an experimental Air Force communications satellite.

NASA's B-52 takes off from Edwards AFB with Pegasus under its right wing pylon.

UCLA graduate students E. David Huckaby and John Mendoza, working under advisor Prof. Ivan Catton, have been modeling high Mach number flows for Pegasus in recent years. Their current efforts are focused on turbulence modeling using the updated version of the PARC3D (NPARC) code, which uses three different models of turbulence: k-epsilon, Baldwin-Lomax, and Baldwin-Barth. A review of some of their earlier work can be found in NASA CR-186023. Beside the Space Shuttle, Pegasus is the only other winged hypersonic vehicle currently being operated by NASA.

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Five seconds after release from the B-52, the first of three solid rocket motors ignites, and with the assistance of the booster's wing, Pegasus begins its 30-minute trip to LEO.

In this issue

(**Students...** *from Page 1.)*

First year grad student Polwin Chan of MANE will perform an optimization study of the APEX high-altitude, balloon-launched aircraft. A recent resurgence of interest in high-altitude (above 100,000 feet) platforms for environmental monitoring, astronomic observation, or surveillance purposes may make this paper study a reality in the future.

(**Pegasus...** *from Page 1.)*

The Pegasus air-launched space booster is produced by Orbital Sciences Corporation and Hercules Aerospace Company to provide small satellite users with a cost-effective, flexible, and reliable method for placing payloads into low-Earth orbit. With the Space Shuttle now landing primarily at Kennedy Space Center, pending good weather, Dryden's space involvement is essentially limited to it's launch support for Pegasus. On this latest launch, the B-52 mother ship was piloted by NASA research pilots Gordon Fullerton and Ed Schneider. F-18 chase pilots were Steve Ishmael (UCLA M.S. '74) and Rogers Smith, who earlier this year flew two flights in the F-104 (#826) for the UCLA jet imaging experiment.

(**Research...** *from Page 4.)*

the stability derivatives are unknown also. We have designed a new filter to estimate the unknown states and parameters, and we are analyzing its features of interest, such as the consistent convergence of parameter estimates, asymptotical optimality of control performances, L_2-stability of the adaptively controlled system, etc. Aspects of practical application to flight control systems are being examined through computer simulations. [Note: Guohua Wang received his Ph.D. in EE from UCLA this past March 1994.]

FSRC Research Roundup

Dennis Braunreiter, Qian Lin, and Sonny Chen:
Estimation of Wind Profiles from Laser Beam Propagation Distortion
Prof. A.V. Balakrishnan (EE) **Ken Iliff (XR)**
Investigation of Refraction Index Patterns of Wind Flow
Prof. K.L. Wang (EE) **Rod Bogue (XRF)**

A lab experiment and computer simulation are being constructed to develop techniques for wind profile estimation from forward laser beam scattering. The scattering arises from ambient optical turbulence shifted by wind normal to the beam propagation path. Weak fluctuation theory or Rytov theory is used as the model for theoretical development and experiment construction. In the lab, optical turbulence was generated initially to observe amplitude fluctuations.

Wind was generated artificially and amplitude fluctuations were observed by a sensitive camera and a high speed photodetector. The camera and photodetector will be used to collect data for on-line and off-line data processing. A circuit is being developed by a senior student to filter, amplify, and isolate signals from the photodetector. The simulation has been started and synthetic random fields have been generated by the Rice random field model.

E. David Huckaby and John Mendoza:
Modeling of High Mach Number Flows for Pegasus
Prof. I. Catton (MANE) **Bob Curry (XRA)**

The updated version of the PARC3D code (NPARC) has been received and is currently being modified to run on the laboratory Silicon Graphics workstation. This new code has three different models of turbulence: k-epsilon, Baldwin-Lomax, and Baldwin-Barth. NASA Lewis is initiating a users group of the new NPARC code. This is part of an effort to create a consortium of users and developers which will interact for the refinement and production of subroutines compatible with the NPARC program. In addition, the new code will be more modular to facilitate this development of subroutines. For our specific use, the new code will enable easier implementation of the k-omega and multi-scale models written in conjunction with D.C. Wilcox. Comparison with the resident models of the code would also then be easier.

The re-simulation of the Pegasus flights has all been completed. Surface heat fluxes and pressure data have been calculated from the numerical data. Preliminary comparisons with the NASA Dryden data show the simulation utilizing the Engquist filter to be the more accurate of the three simulations. The three types of simulation were: 1) large amount of artificial dissipation without the filter, 2) small amount of artificial dissipation without the filter, 3) small amount of artificial dissipation with the filter.

Eric Shank: ***Human-Computer Interaction in Complex Systems***
Prof. W. J. Karplus (CS) **Mary Shafer (XRDD)**

Eric Shank is preparing to spend the summer at Dryden focusing on his work in visualization of flight data. He is developing a methodology for the construction of domain-specific visualizations which show parameter values in context for easy comprehension. The inherent physical, logical and mathematical relationships among aircraft parameters are used to structure and organize the presentation of the information on screen. Observations of displays and operations in the control room during X-31 and HARV flight tests continue to be inspirational in the development of this work.

Research summaries were once again submitted by graduate students and/or their professors. Project titles and NASA monitors are listed alongside.

NASA Colloquium '94

This Spring's NASA Colloquium at Dryden will be held Friday June 3rd from 10:00am to 3:00pm in the ISF Auditorium. A map of directions from UCLA to Dryden by car is included on page 5. During the day long colloquium, NASA branch chiefs and representatives will present areas of active research which could use direct or indirect support from the university community. This opportunity will provide professors with useful information in preparation of future proposals or as a starting point for spin-off research projects. Various resources and facilities at Dryden will also be mentioned for available use by UCLA graduate students and professors.

The last Colloquium held at Dryden was in the Fall of 1991. This Spring's Colloquium marks a change in scheduling with the yearly Research Review, which has traditionally been in the Spring. Research Review meetings are still held in the LA area, with the next one scheduled for later this Fall. Whereas the upcoming Colloquium primarily features Dryden speakers, the Research Review allows graduate students to showcase their latest research findings.

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Logan Brashear:
Estimation of Air Data Parameters During Dynamic Flight
Prof. N. Levan (EE) Timothy Moes and S. Tony Whitmore (XRA)
Logan Brashear and his advisor Prof. Nhan Levan have continued their research with NASA engineers Tim Moes and Dr. Tony Whitmore on the performance of air data probes during dynamic flight. They are currently developing trajectory estimation software which will serve as a general engineering application, as well as a platform for testing models for local air flow. This will aid in "identifying" the position error and covariance for air data probes.

Timothy Gerk: ***Modeling of a Lobed Injector/Burner for NOx Reduction in High Speed and Advanced Subsonic Aircraft***
Prof. A. R. Karagozian (MANE) Stephen Corda (XRP) and Ken Iliff (XR)
Development of the lobed fuel injector/burner is being performed in an asymptotic and numerical study by Tim Gerk, an M.S. student in MANE. Tim is concerned with quantifying an expected ignition delay for this injector, and therefore quantifying the increased degree of fuel/air premixedness when the flame is initiated. The flowfield downstream of the injector is represented as an infinitely extended series of counter-rotating vortices. A sinusoidally shaped strip of fuel which will emit from the mixer-injector is represented as the initial condition. The frozen flow, i.e., the case where to first order approximations there is no reaction in the flowfield, has been solved by Tim. He is now examining alternative asymptotic techniques in order to be able to predict the thermal runaway that leads to ignition. The results of these asymptotic analyses of the reaction, using a reduced chemical mechanism, will be compared with fundamental results for strained (flame) interfaces with full combustion chemistry.

Oshin Peroomian:
Instabilities in Compressible Confined Mixing Layers
Prof. R. E. Kelly (MANE) Fanny Zuniga (XRA)
The effects of density gradients on the stability characteristics of subsonic and supersonic confined shear layers are currently being investigated. Both linear analysis and numerical simulations are being used in order to understand the initial and long time behavior of compressible confined shear layers under the action of density gradients. Currently, linear analysis is being conducted using both "approximate" and "exact" velocity profiles. Some interesting results are being obtained for the acoustic wall modes in the supersonic shear layer case.

Olivier Delabroy and Ivan Lam:
In-Flight Imaging of Transverse Jet and Lobed Injector Mixing Processes
Prof. O. I. Smith (ChemE) and Prof. A. R. Karagozian (MANE)
Al Bowers (XRA) and Ken Iliff (XR)
The experimental portion of the lobed injector/burner project has begun with cold flow experiments to be conducted at UCLA, in anticipation of future flight tests at NASA Dryden. Olivier Delabroy, a Ph.D. student at Ecole Centrale de Paris under additional support from SNECMA, is working with Ivan Lam, an M.S. departmental scholar in MANE, on the UCLA-based experiments.

The cold (non-reacting) flow tunnel for examination of mixing processes downstream of the lobed injector has been completed. Fuel is replaced in the cold flow experiment by CO2 (which has the same molecular weight as propane). The lobed injector, consisting of two sinusoidally loaded plates, has been formed in UCLA's SEAS machine shop out of aluminum and using a numerically controlled machine (EDM). The mixing tunnel itself is constructed of wood, with optical access in the spanwise

FSRC Research Roundup - *continued*

and streamwise directions for flow visualization. Expected strain rates in the streamwise direction are estimated to be above 2000 s-1, so that ignition should be delayed in a combustion application, thus potentially reducing NOx emissions for high speed aircraft.

PLIF (planar laser-induced fluorescence) of seeded acetone will be performed in the mixing tunnel. Acetone is a reliable seed for PLIF if the temperature of the flow is constant; acetone will allow concentrations and mixing measurements to be made in non-reacting flow. Olivier and Ivan will use a XeCl excimer laser in the PLIF experiments, in order to image cross-sectional slices of the mixing layer onto a CCD camera. The evolution of the regions of mixed and unmixed flow will be measured and compared with theoretical predictions obtained by Tim Gerk.

Progress continues with model comparisons and data reduction from the in-flight transverse jet experiment, successfully flown and operated earlier this year on Dryden's F-104. Altitude chamber ground tests were recently performed to verify jet velocity and total pressure measurements. A draft detailing the experiment and results has been submitted to AIAA for conference presentation.

Gustave Stroes: ***Leading Edge Cooling***
Prof. I. Catton (MANE) and Prof. V. Dhir (MANE)
Bob Curry (XRA)
Experimental studies comparing the wicking power of triangular and sinusoidal groove shapes are almost complete. Some interesting results have been obtained. Contrary to our expectations, the sinusoidal channels provide a smaller wetted area than the triangular channels when at the same angle of inclination and subject to the same heat load. The sinusoidal shape is thus not as capable of wicking liquid up the plate. On the one hand this seemed disappointing as an increase in efficiency was hoped for. But the results have caused us to question which parameters are really important as far as heat pipe design is concerned. For example, although the sinusoidal channels do not have the same wicking power as the triangular channels, they are capable of removing the same amount of heat from a smaller surface area, which would allow a more compact heat pipe design. Thus, which shape is better depends on how one interprets the results. These issues should be clarified when the data is complete and can be graphed.

Anindita Datta: ***Numerical Modeling of Atmospheric Transients for High Performance Aircraft***
Prof. M. Wurtele (AtmosSci) L. Jack Ehernberger (XRA)
Our research concerning the dynamics of propagation of gravity and gravity-inertial waves continues in full swing. Encounter with singular levels being one of the primary mechanisms for breakdown of gravity and gravity-inertial waves, we have systematically examined the characteristics of the flow pattern when a propagating monochromatic wave encounters singular levels in rotating, shear flow. These results have allowed us to consider more realistic forcing profiles. Our theoretical findings agree very well with numerical simulations, the simulations providing us with additional information about the nonlinear development of the disturbances.

There are strategic components to this research, in addition to the scientific interest in the dynamics. In operational weather forecasting models, it has been found necessary to incorporate the effect of gravity wave breakdown. It may also turn out that gravity-inertia disturbances are important for accurate predictions for flow at higher levels. Further, as high flying supersonic aircraft (including possibly the National Aerospace Plane) begin to cruise at levels far above the tropopause it will be essential for aeronautical agencies such as the Dryden Flight Research Center to understand the potential impact of gravity-inertia wave breakdown and associated turbulence. This would involve knowing the intensity and wave spectrum of the breakdown process, which is the present goal of the project.

Brian Dempsey and Ben Tan: ***Fluid Flow & Heat Convection Studies for Actively Cooled Airframes***
Prof. A. Mills (MANE) Bob Quinn (XRS)
Since the last update in January, the jet impingement experiment has been fully assembled and tested. NASA Dryden has provided support for this project by supplying calibration data for our pressure transducer. It is anticipated that the Dryden calibration lab will be useful in the future for temperature calibrations of thermocouples, thermistors, and the thermochromic liquid crystals. Some initial results have been generated for a submerged circular heated jet, impinging on a flat plate. The results prove the feasibility of the method for generating heat transfer coefficients. The tests have also validated the data gathering, image processing, and data reduction software. However, since submerged jets entrain air at a different temperature, the heat transfer is difficult to characterize and compare to previous studies. The next set of tests will be designed to provide data which will establish the accuracy of the method by comparing it to other studies.

Guohua Wang: ***Modeling, Identification and Control with Applications to Flight Vehicles***
Prof. A. V. Balakrishnan (EE) Ken Iliff (XR)
Upon the completion of our research of a stochastic adaptive control (SAC) problem where the system control derivatives are uncertain, we have moved on to studying the case in which

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